

## CLAIMS

1. An optical device, comprising:  
multi-mode waveguides positioned on a base such that a plurality of the  
5 waveguides serve as input waveguides and one or more of the waveguides serve  
as an output waveguide, the waveguides intersecting one another such that light  
signals traveling along a plurality of the input waveguides are combined onto an  
output waveguide, at least a portion of the input waveguides including a taper  
configured to taper the width of a light signal traveling along the input waveguide.  
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2. The device of claim 1, wherein a thickness of at least a portion of the  
contraction tapers remains substantially constant along their length.
3. The device of claim 1, wherein at least a portion of the contraction tapers  
15 taper from an expanded end to a contracted end having a width less than 30 % of  
the width of the expanded end.
4. The device of claim 1, wherein at least a portion of the contraction tapers  
have a contracted end with width greater than 12  $\mu\text{m}$ .  
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5. The device of claim 1, wherein at least a portion of the contraction tapers  
have a taper ratio in a range of than 8:1 to 200:1, the taper ratio being a ratio of the  
taper length:the taper width.
- 25 6. The device of claim 1, wherein at least one output waveguide includes an  
expansion taper configured to expand a light signal traveling along the output  
waveguide.
7. The device of claim 6, wherein the expansion tapers do not taper  
30 vertically.

8. The device of claim 6, wherein the expansion tapers expand from a contracted end to an expanded end, the contracted end having a width less than 80 % of the width of the expanded end.
- 5 9. The device of claim 6, wherein at least a portion of the expansion tapers have a taper ratio in a range of 8:1 to 200:1, the taper ratio being a ratio of the taper length:the taper width.
- 10 10. The device of claim 1, wherein one or more of the waveguide intersections is constructed such that a waveguide configured to carry output from the intersection has a width greater than a width of each waveguide configured to carry input to the intersection.
- 15 11. The device of claim 1, wherein lateral sides of the waveguides extend down to the base.
12. The device of claim 1, wherein the waveguides are silicon.
- 20 13. The device of claim 1, wherein one or more of the waveguides end at a facet that is substantially vertical relative to a base, each facet being angled at less than ninety degrees relative to a direction of propagation of a light signal traveling along the waveguide at the facet.
- 25 14. The device of claim 1, further comprising:  
one or more inactive regions spaced apart from the waveguides so as to define waveguide trenches adjacent to the waveguides.
- 30 15. The device of claim 1, wherein the waveguides have a thickness between 16  $\mu\text{m}$  and 75  $\mu\text{m}$  and a width between 16  $\mu\text{m}$  and 75  $\mu\text{m}$ .
16. The device of claim 1, wherein the thickness of the waveguides is more than 1.4 times the width of the waveguide.

17. The device of claim 1, further comprising:  
a plurality of light sources for generating light signals, each light source  
being positioned in a recess on the optical device such that a light signal generated  
5 by the light source enters an input waveguide.

18. An optical device, comprising:  
multi-mode waveguides positioned on a base such that a plurality of the  
waveguides serve as input waveguides and one or more of the waveguides serve  
10 as an output waveguide, the waveguides intersecting one another such that light  
signals traveling along a plurality of the input waveguides are combined onto an  
output waveguide, one or more output waveguides including a expansion taper  
configured to taper the width of a light signal traveling along the input waveguide.

15 19. The device of claim 18, wherein a thickness of at least a portion of the  
contraction tapers remains substantially constant along their length.

20. The device of claim 18, wherein at least a portion of the expansion tapers  
taper from an expanded end to a contracted end having a width less than 30 % of  
20 the width of the expanded end.

21. The device of claim 18, wherein at least a portion of the expansion tapers  
have a contracted end with width greater than 10  $\mu\text{m}$ .

25 22. The device of claim 18, wherein at least a portion of the expansion tapers  
have a taper ratio in a range of than 8:1 to 200:1, the taper ratio being a ratio of the  
taper length:the taper width.

23. A method of forming an optical device, comprising:  
30 etching a wafer having silicon positioned on a base so as to form a  
plurality of mutli-mode waveguides on the base, the waveguides formed such that  
a plurality of the waveguides serve as input wavegudes and one or more of the

5 waveguides serve as an output waveguide, the waveguides intersecting one another such that light signals traveling along a plurality of the input waveguides are combined onto an output waveguide, at least a portion of the input waveguides being formed so as to include tapers configured to contract a width of a light signal traveling along the input waveguide toward the output waveguide.

10 24. The method of claim 23, wherein at least a portion of the contraction tapers are formed such that a thickness of the taper remains substantially constant along a length of the contraction taper.

25. The method of claim 23, wherein at least a portion of the contraction tapers taper from an expanded end to a contracted end having a width less than 80 % of the width of the expanded end.

15 26. The method of claim 23, wherein at least a portion of the contraction tapers are formed so as to taper from an expanded end to a contracted end with width greater than 12  $\mu\text{m}$ .

20 27. The method of claim 23, wherein at least a portion of the contraction tapers are formed so as to have a ratio of a taper length:a taper width in a range of 8:1 to 200:1.

25 28. The method of claim 23, wherein at least one output waveguide is formed so as to include an expansion taper configured to expand a light signal traveling along the output waveguide from the an input waveguide.

29. The method of claim 28, wherein the expansion tapers is formed such that the expansion taper does not taper vertically.

30 30. The method of claim 28, wherein the expansion tapers expand from a contracted end to an expanded end, the contracted end having a width less than 80 % of the width of the expanded end.

31. The method of claim 28, wherein at least a portion of the expansion tapers have a taper ratio in a range of 8:1 to 200:1, the taper ratio being a ratio of the taper length:the taper width.

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32. The method of claim 23, wherein one or more of the waveguide intersections is formed such that a waveguide configured to carry output from the intersection has a width greater than a width of each waveguide configured to carry input to the intersection.

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33. The method of claim 23, wherein the etch is performed for a duration sufficient to form lateral sides of the waveguides down to the base.

34. A method of forming an optical device, comprising:

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etching a wafer having silicon positioned on a base so as to form a plurality of mutli-mode waveguides on the base, the waveguides formed such that a plurality of the waveguides serve as input wavegudes and one or more of the waveguides serve as an output waveguide, the waveguides intersecting one another such that light signals traveling along a plurality of the input waveguides are combined onto an output waveguide, at least a portion of the output waveguides being formed so as to include tapers configured to expanact a width of a light signal traveling along the output waveguide from the input waveguides.

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